

Irrigation Kuznets Curve, Governance and Dynamics of Irrigation Development: A Global Cross-Country Panel Analysis from 1972 to 1991

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Using a global analysis across 66 countries, this study empirically validates the presence of an Environmental Kuznets Curve (EKC) relationship for irrigation development. That is to show that there is an inverted U-shaped relationship between the level of irrigation and income. This implies that the relative importance of irrigation is greater during the earlier stage of development of a society but once the economy grows, the relative importance of irrigation and water uses in agriculture declines compared to water uses in other sectors. This information has major implications in deriving demand for water uses in agriculture, and for efficient irrigation planning, in general.

The major purpose of this study is to empirically test the hypothesis that there is a systematic relationship between irrigation development and a society's per capita income level. In line with the relationship between income and other environmental factors in past studies, the irrigation-income relationship is tested in this study using the Environmental Kuznets Curve (EKC) hypothesis referred to as the EKC relationship for irrigation, or as the Irrigation Kuznets Curve hypothesis, or IKC in short. The EKC hypothesis suggests an inverse U-shaped (or concave) relationship between the level of environmental degradation and income. In other words, the EKC hypothesis implies that some form of environmental deterioration is inevitable during the initial stage of development, but subsequent increases in societal income would generate incentives to improve the environmental quality. Along this line, the EKC relationship for irrigation suggests that societal demand for irrigation is greater at the initial stage of development and that it declines as societal income reaches a certain critical limit, i.e., there is an inverted-U-shaped relationship between the level of irrigation and societal income level. This information has large implications on estimating irrigation demand and water uses in agriculture and in other sectors, and in irrigation planning, in general.

In this study, the EKC hypothesis for irrigation (i.e., IKC) is examined across 66 tropical countries from Asia, Africa and Latin America using national-level annual data from 1972 to 1991. The IKC model is once estimated for 66 tropical countries, and separately for 13 countries from Asia where more than two-thirds of the global irrigated land is located. Two measures of irrigation are used, "percentage of crop area irrigated" and "relative change in net irrigated area." In addition to estimating irrigation and income relationship, effects of other broad-level institutions and policy factors on irrigation are also analyzed. These other policy variables included are: governance (sum total of political and civil liberty indices), cereal yield, agricultural value added, manufacturing value added growth, rural population density, economic growth rate, and per capita electricity use.

The empirical results provide strong evidence for the existence of an EKC relationship for the two measures of irrigation used, and for both the tropical-global and the Asia IKC models. This means that the pace of irrigation development is faster at the initial stage of a country's development and that it will be at a slower rate at the later stage of development. A typical figure of IKC simulated from the Asia IKC model is illustrated in figure 1. This study demonstrates the fact that the

underlying income effect and development process are critical components of irrigation development and for emergence of the IKC relationship.

The study also demonstrates that macro economic, structural and institutions-related factors of a nation also affect the irrigation level at any given moment. This means that we can adjust the level and scale of irrigation development in a nation (region) also by altering these institutional and policy factors. An environmental ramification of the analysis on EKC for irrigation is that the irreversible damage to the water-sector environment can be potentially avoided by selecting appropriate policy instruments. The information on the marginal effect of factors derived in this study will be useful in designing policies for sustainable use of water resources in a region, and potentially avoiding irreversible damage to the environment. This is also called a policy-tunneling process.

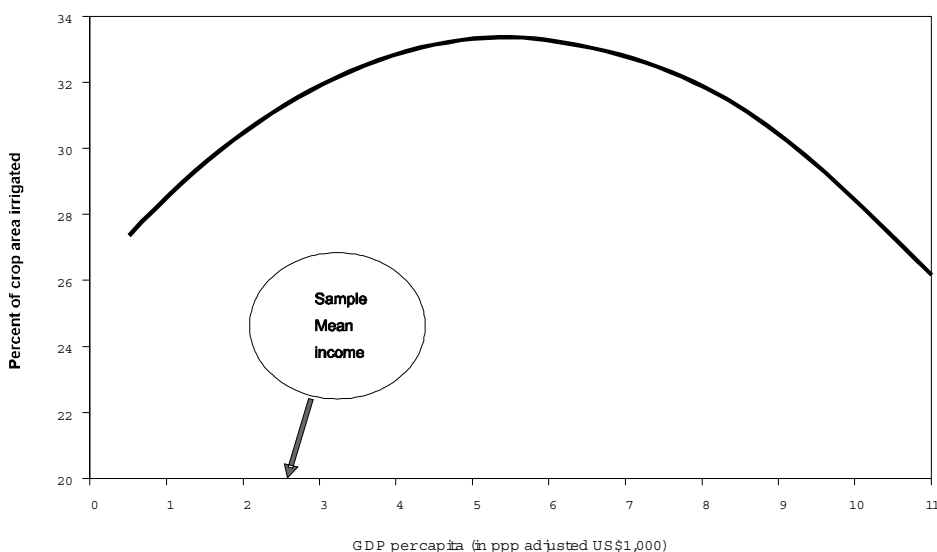
The empirical findings also imply that there is no leapfrogging in the process of irrigation and agricultural development and management of natural resources in an economy. Each economy (society) may have to pass this EKC type of trajectory. The pace of irrigation development, however, may differ across countries (regions) as per the variation in the climatic, hydrological and other policy and institutional factors.

In other words, effective irrigation planning needs to also account for these economic and institutional forces and other structural factors of the nation.

The non-linear relationship (elasticity value) estimated between irrigation and a nation's income can be used for better forecasting irrigated-area demand in an economy. This study demonstrates that the income elasticity of irrigation (irrigated land) has a nonlinear relationship with the per capita income, as opposed to the zero-income elasticity of irrigation assumed in most past studies. The non-linear income-elasticity values (parameters), if incorporated in an irrigated-area forecasting model, could greatly improve the accuracy and efficiency of the performance of past irrigation-demand forecasting analyses. Irrigation area and water-demand analyses are so far mostly based upon per capita requirement type of forecasting techniques, which ignore the underlying income effects and societal substitutional behavior over resources use decisions, even when there is a large extent of change in income and relative price structures over time.

In addition, the empirical findings derived here also provide improved information for policy debates on water uses for food production versus environmental protection, and how these water allocation decisions are affected by the underlying income and institutional factors of a region.

Figure 1. Irrigation Kuznet Curve diagram for Asia generated from the Asia model, 1972-1991.



Note: The IKC diagram is generated by taking the regression coefficients from the Asia model of the study with an income range selected from US\$500 to US\$11,000 (Purchasing Power Parity (PPP) adjusted value).